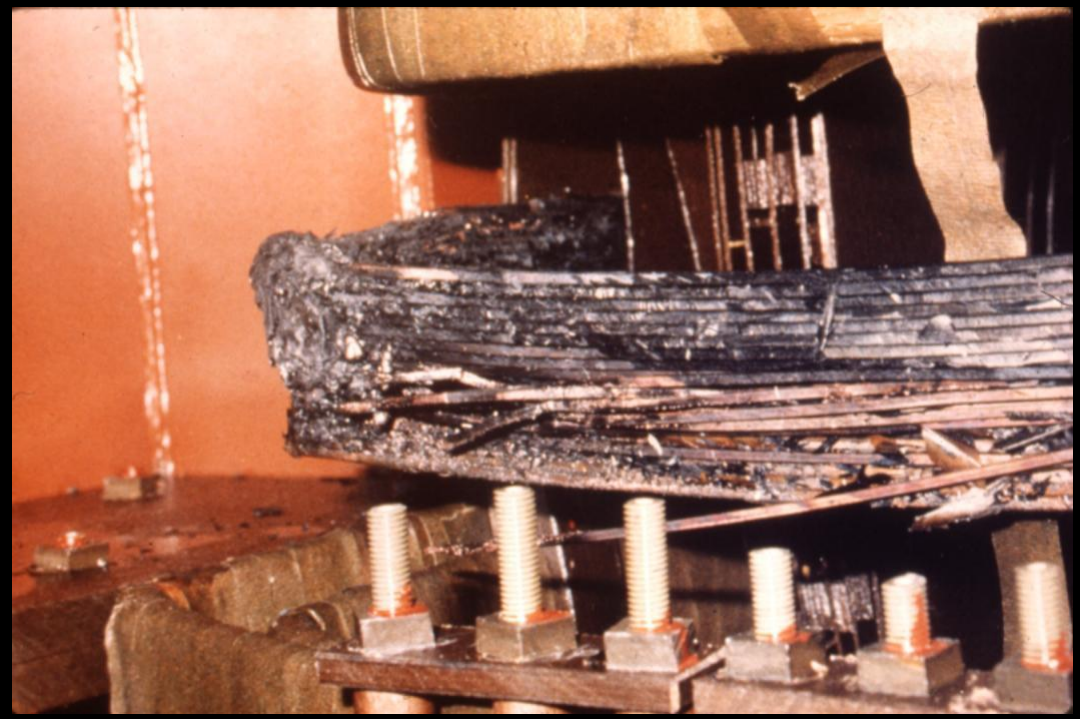
In 1989, A Massive Blackout Left Millions without Power for Twelve Hours

Image from a NASA Artist’s Concept

Transformer Damaged from Geomagnetically Induced Current (GIC)



Images Provided by J.G. Kappenman, used with permission.

Short-wave Radio Communications Affected

Jammed radio signals into Russia from Radio Free Europe

Audio is provided with permission from amateur radio astronomer, Radio Jove participant,
and
NASA Citizen Scientist Thomas Ashcraft.

Auroral Oval Moved South (North) Toward the Equator, Aurorae Seen in Florida

Jan 20, 2016: Image taken from the International Space Station (ISS) by
NASA astronaut Scott Kelly and European Space Agency (ESA) astronaut Tim Peake.
Lights from the Pacific Northwest are seen below the Aurorae.

What Caused these Problems?
i.e., Power Outage, Short-Wave Fade,
Aurorae Seen far to South (or North)
Could it be:

Earthquakes?

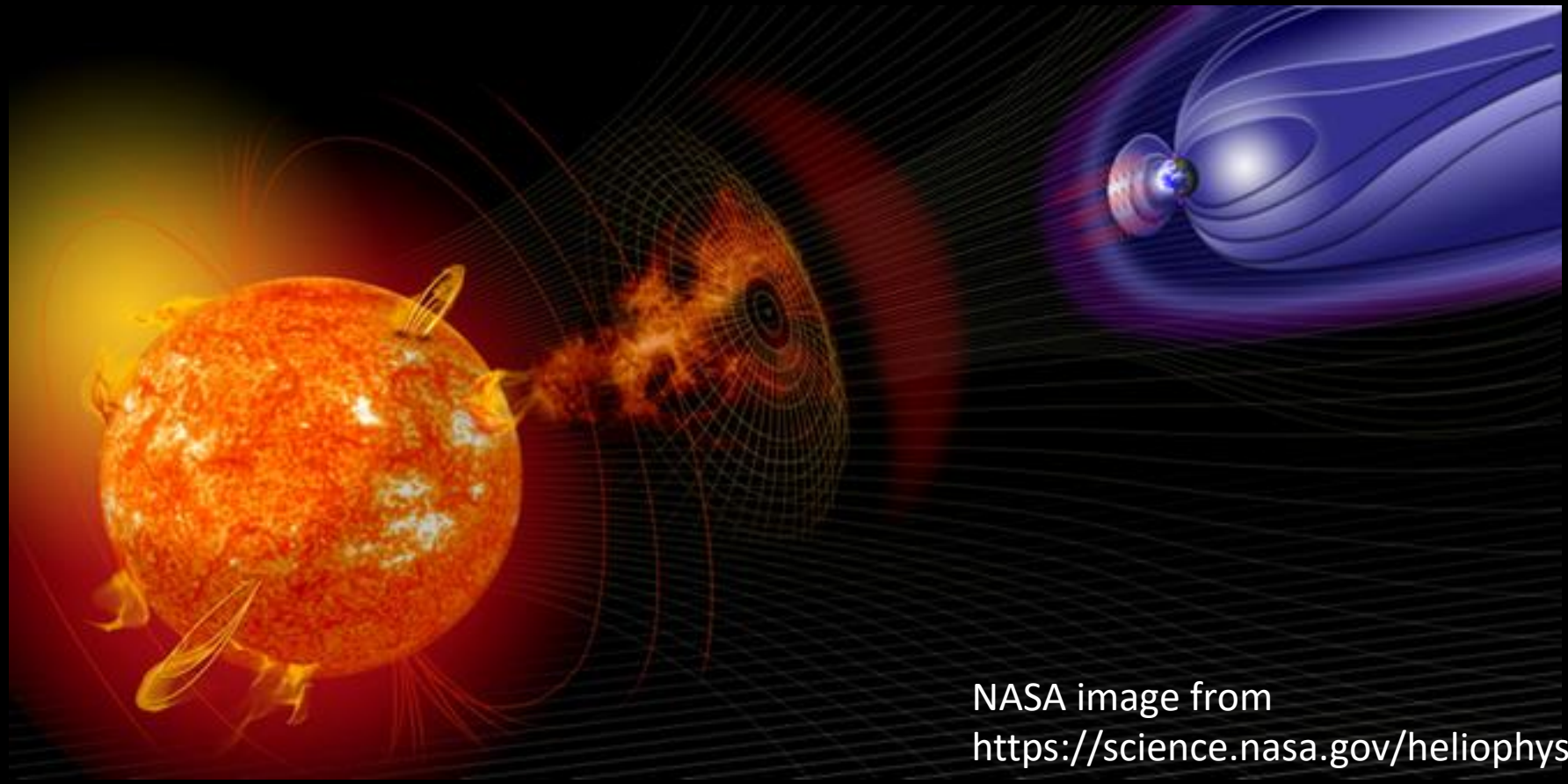
Tornadoes?

Hurricanes?

Alien Invasion?

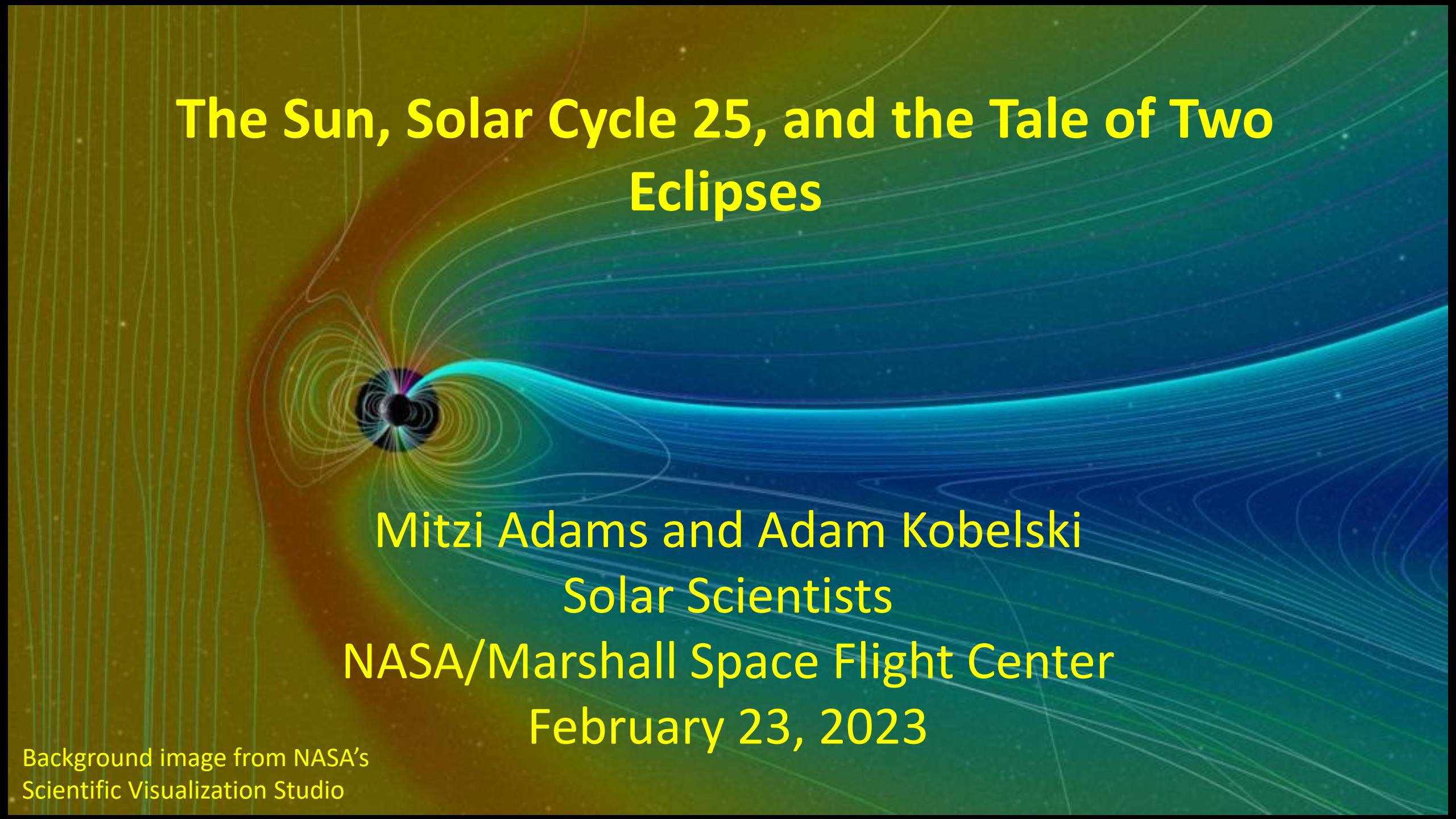
The Answer Is ---

Space Weather!



NASA image from
https://science.nasa.gov/heliophysics/space-weather

The Sun, Solar Cycle 25, and the Tale of Two Eclipses



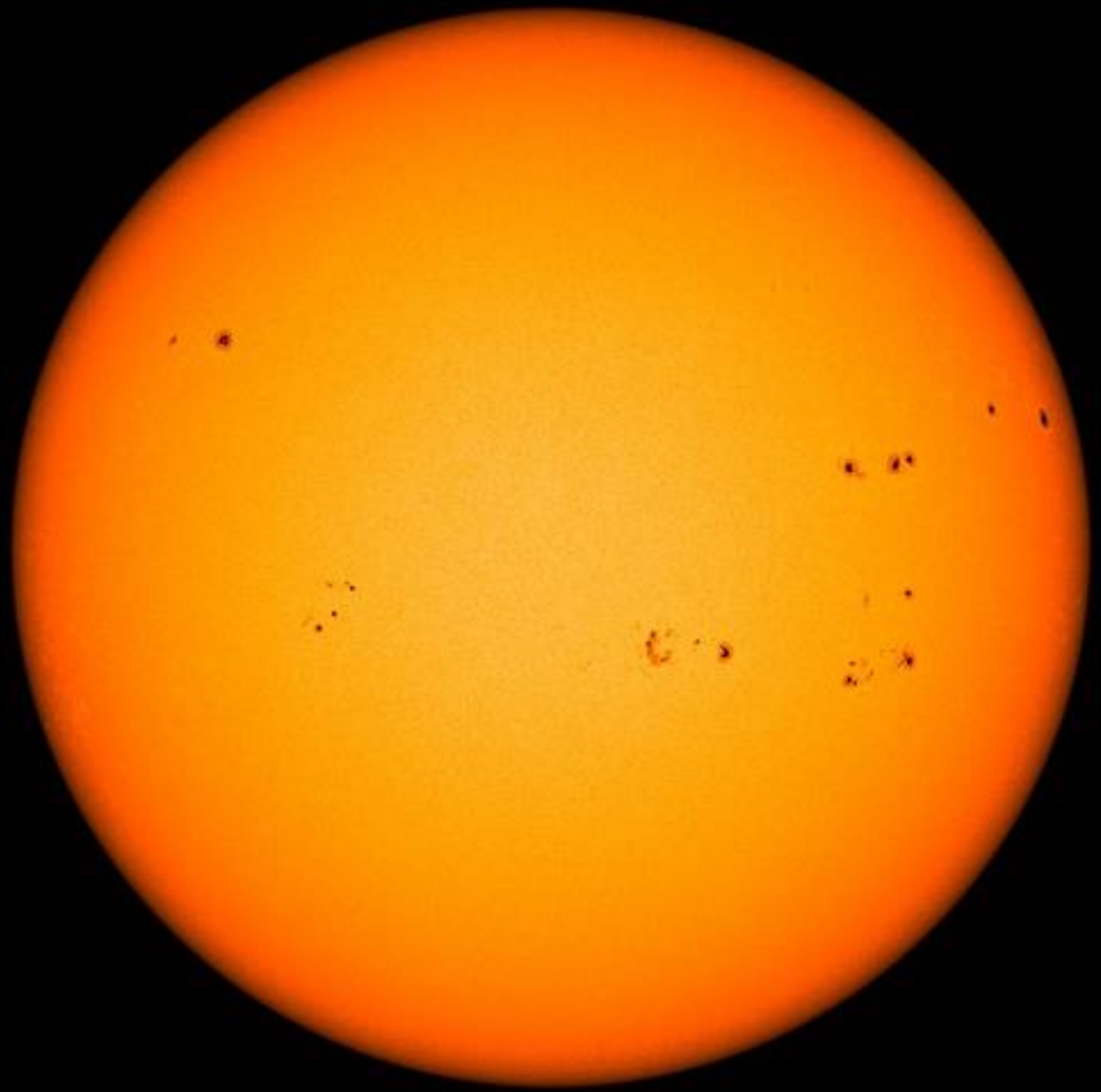
Mitzi Adams and Adam Kobelski
Solar Scientists
NASA/Marshall Space Flight Center
February 23, 2023

Background image from NASA's Scientific Visualization Studio

What We See on the Sun, our Closest Star

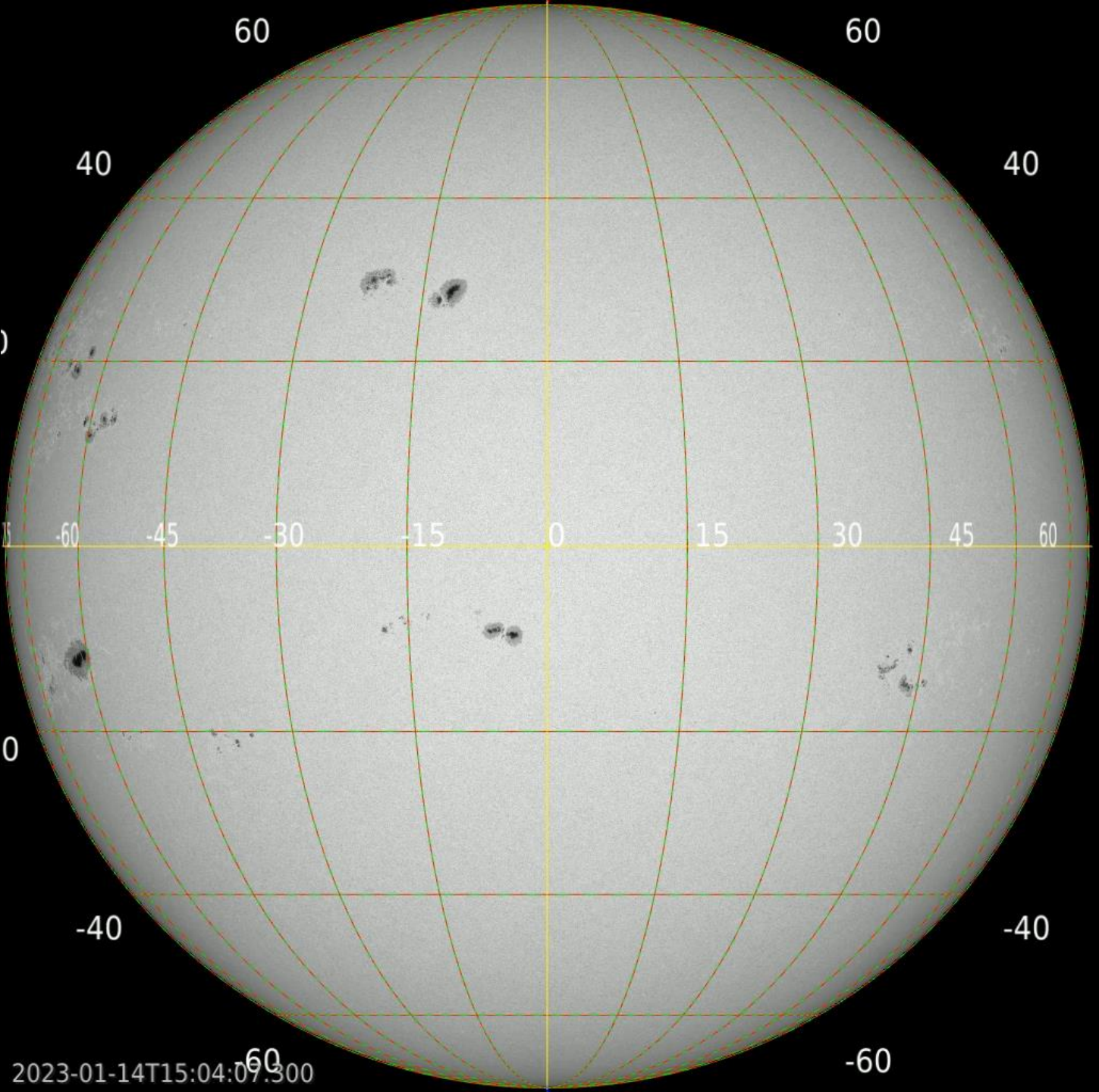
The Sun is a Star

The Sun produces light all “colors” of the EM spectrum:
γ rays, X rays, UV, visible, IR, μwave, radio.



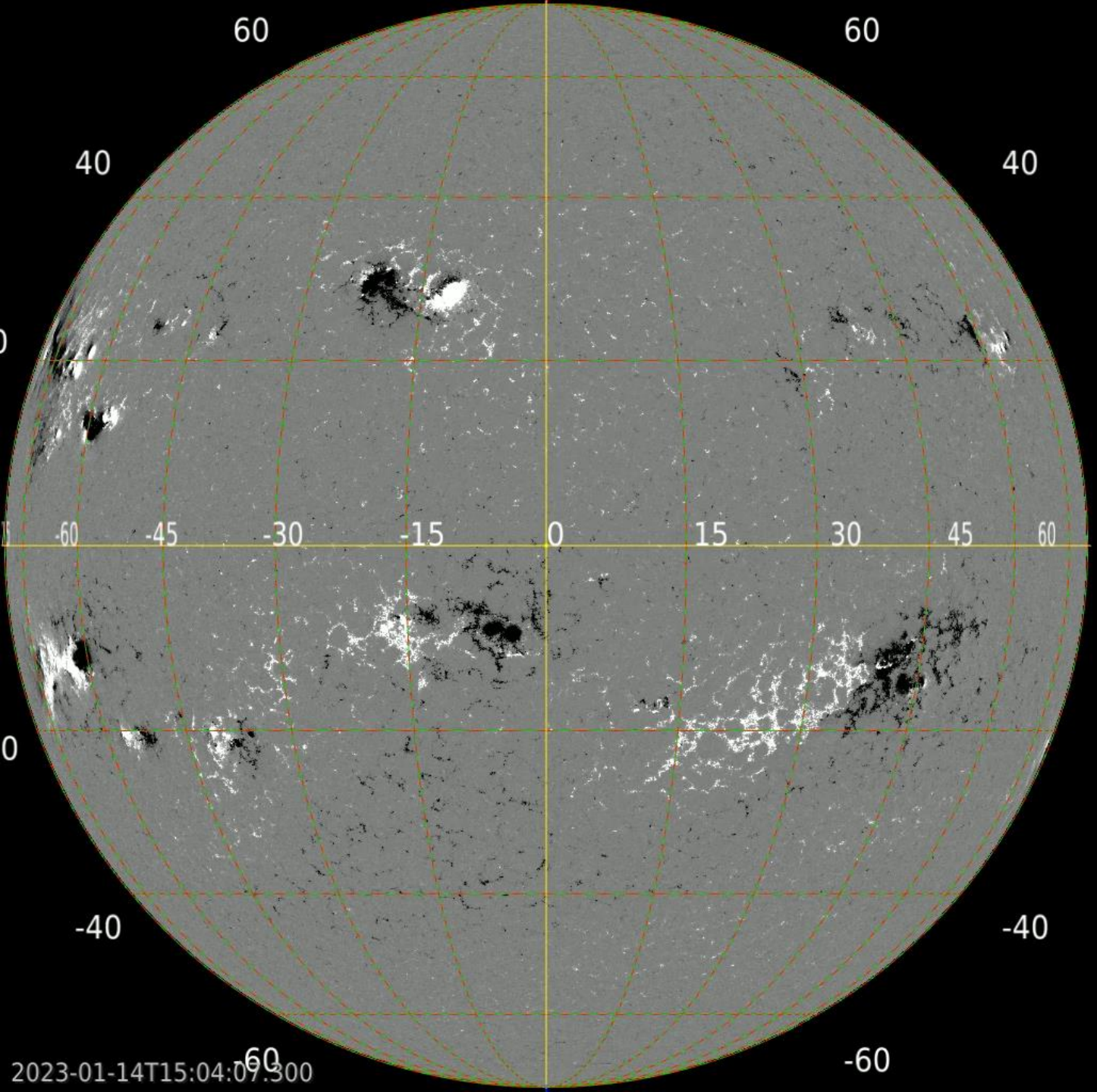
The Sun produces a “wind” of charged particles, electrons and protons, which flows steadily all the time.

The Photosphere — with Sunspots!



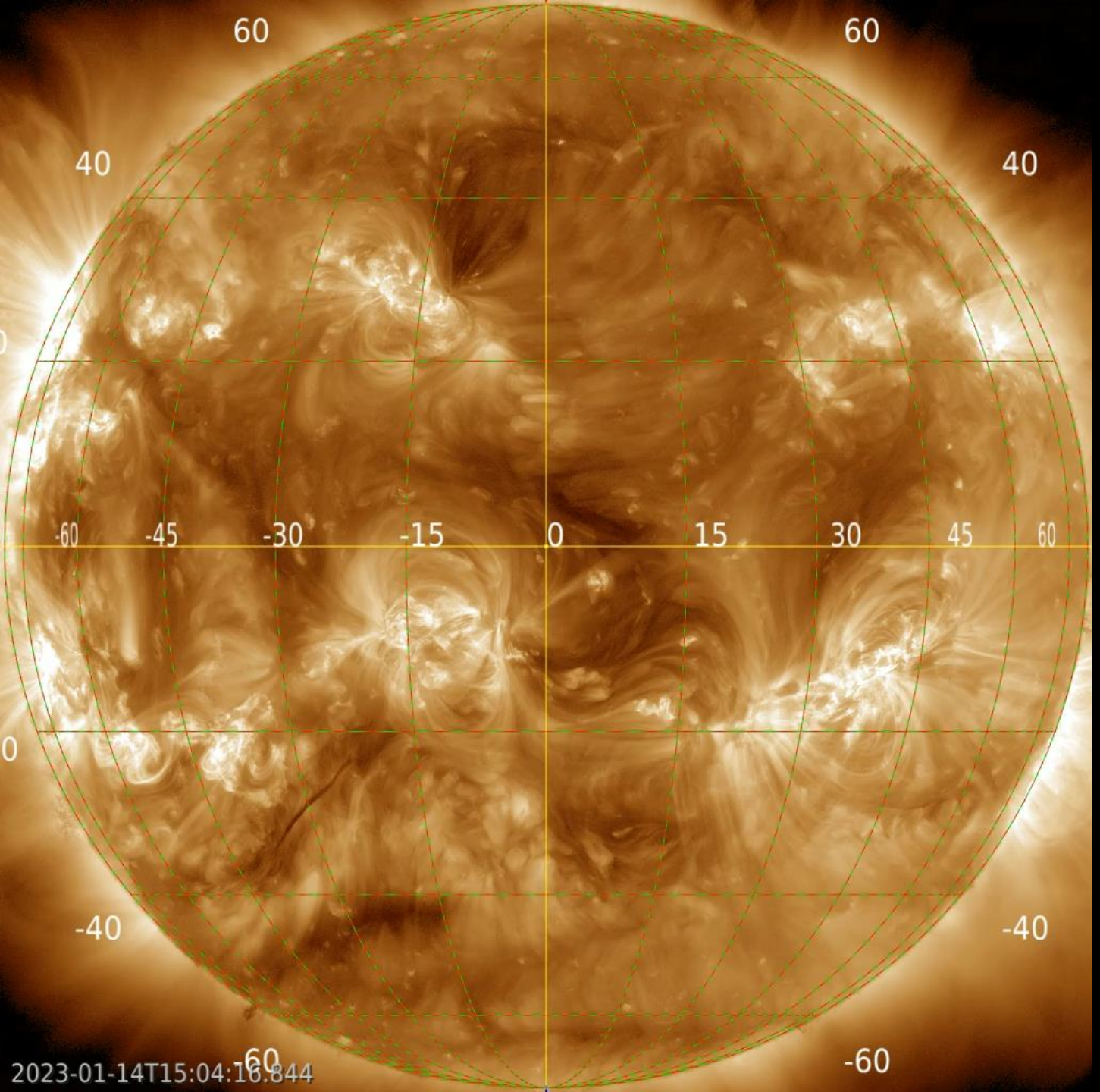
This Recent Image from the Solar Dynamics Observatory Shows Sunspots

The unspotted area is about 6000 K (10,000 F), sunspots are about 3700 K (6200 F) in the darkest part of the Sunspot (Umbra)



This Image, also from the Solar Dynamics Observatory shows the Magnetic Field that is associated with the Sunspots

Sunspots are Cooler than their surroundings since the Magnetic Field holds back Heat from below



This Image, also from the Solar Dynamics Observatory shows the Corona over the same period

The hot (~1.8 Million °F!) plasma traces magnetic field lines from sunspots

Due to ‘differential rotation’, the equatorial region rotates about once every ~25 days, the poles closer to ~35 days

This rotation drags the magnetic field with it, causing the ‘solar cycle’

Sunspot Cycles Since ~1610

What Happened in 1610?

Galileo Galilei and Thomas Harriot observed sunspots through a telescope

Johannes and David Fabricius and Christoph Scheiner made observations in 1611

Johannes Fabricius published about sunspots later in 1611

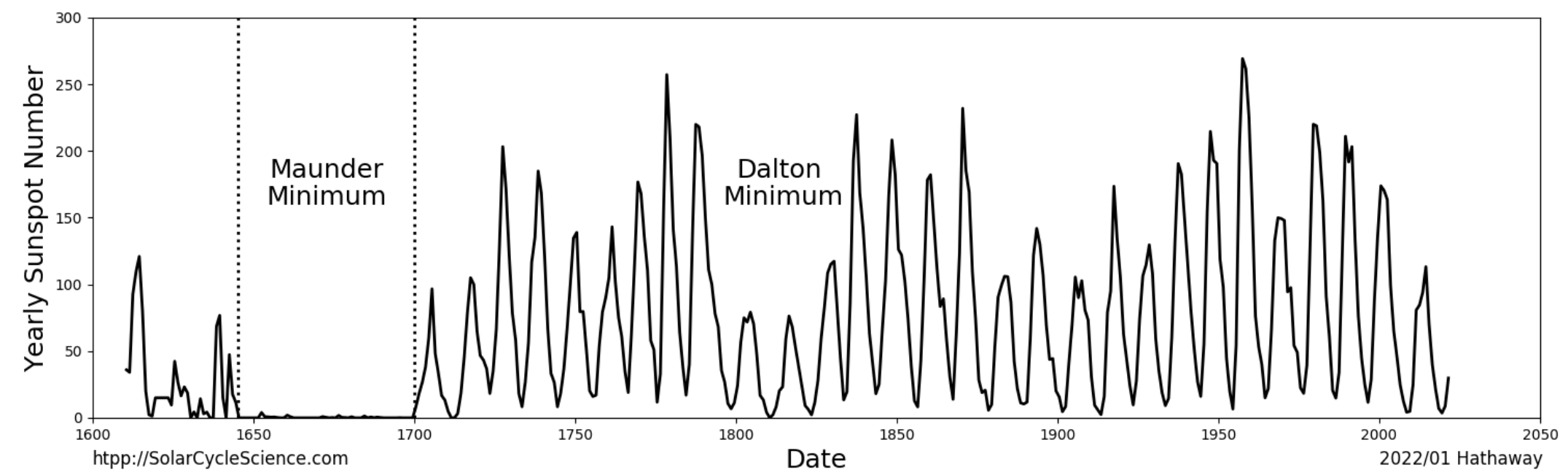
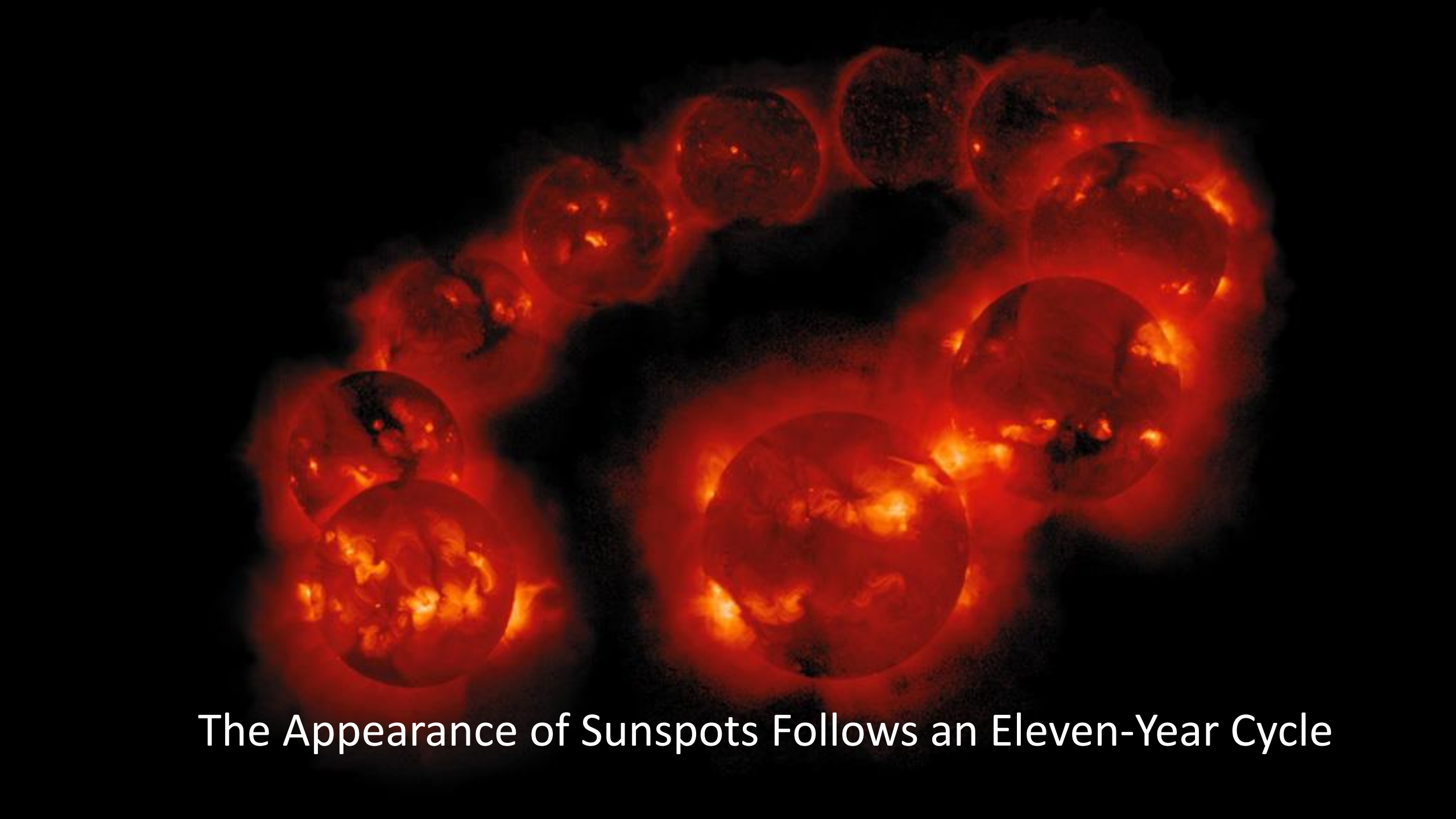


Image Used with Permission from Dr. David Hathaway



The Appearance of Sunspots Follows an Eleven-Year Cycle

Sunspot Cycle

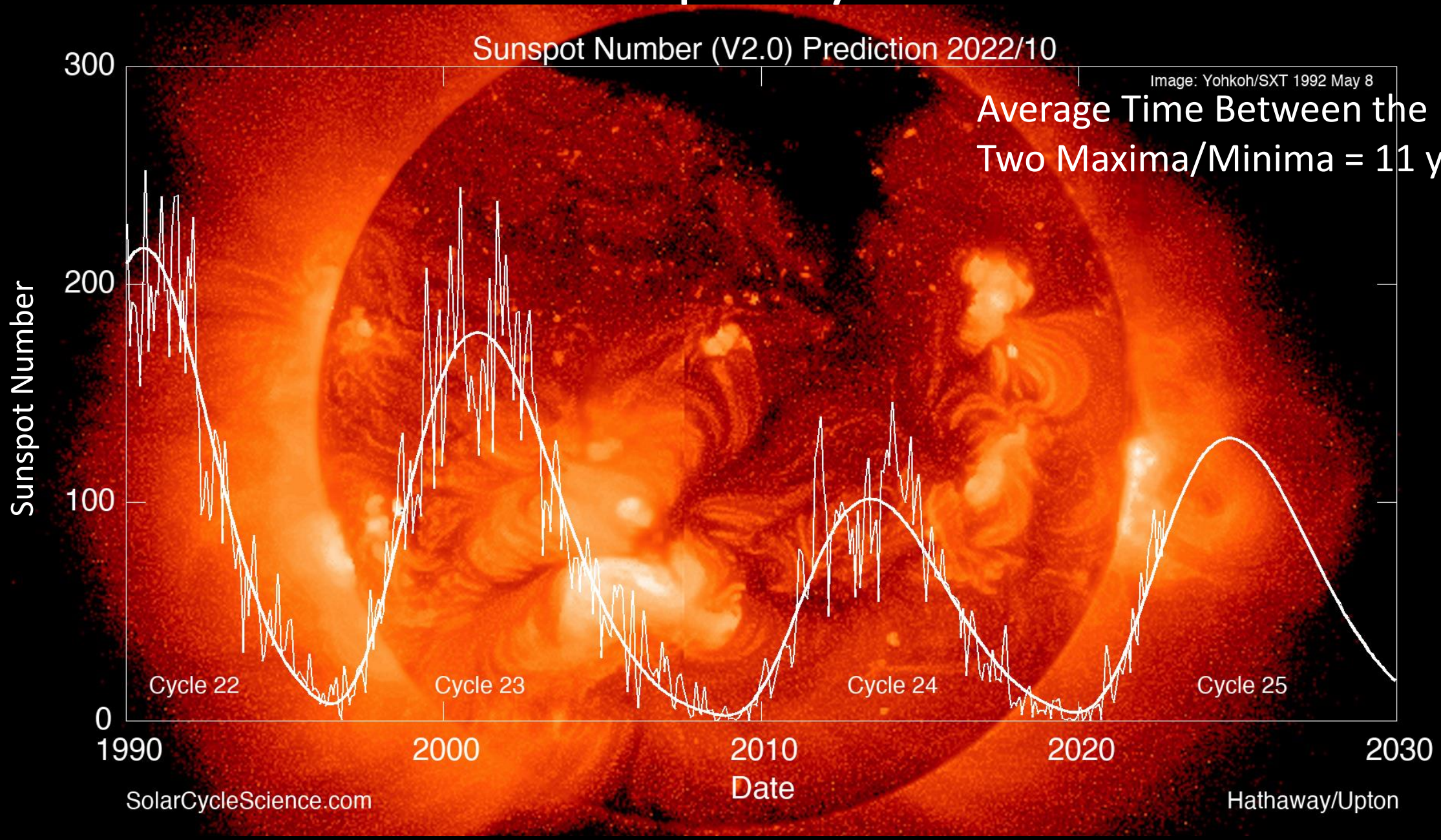


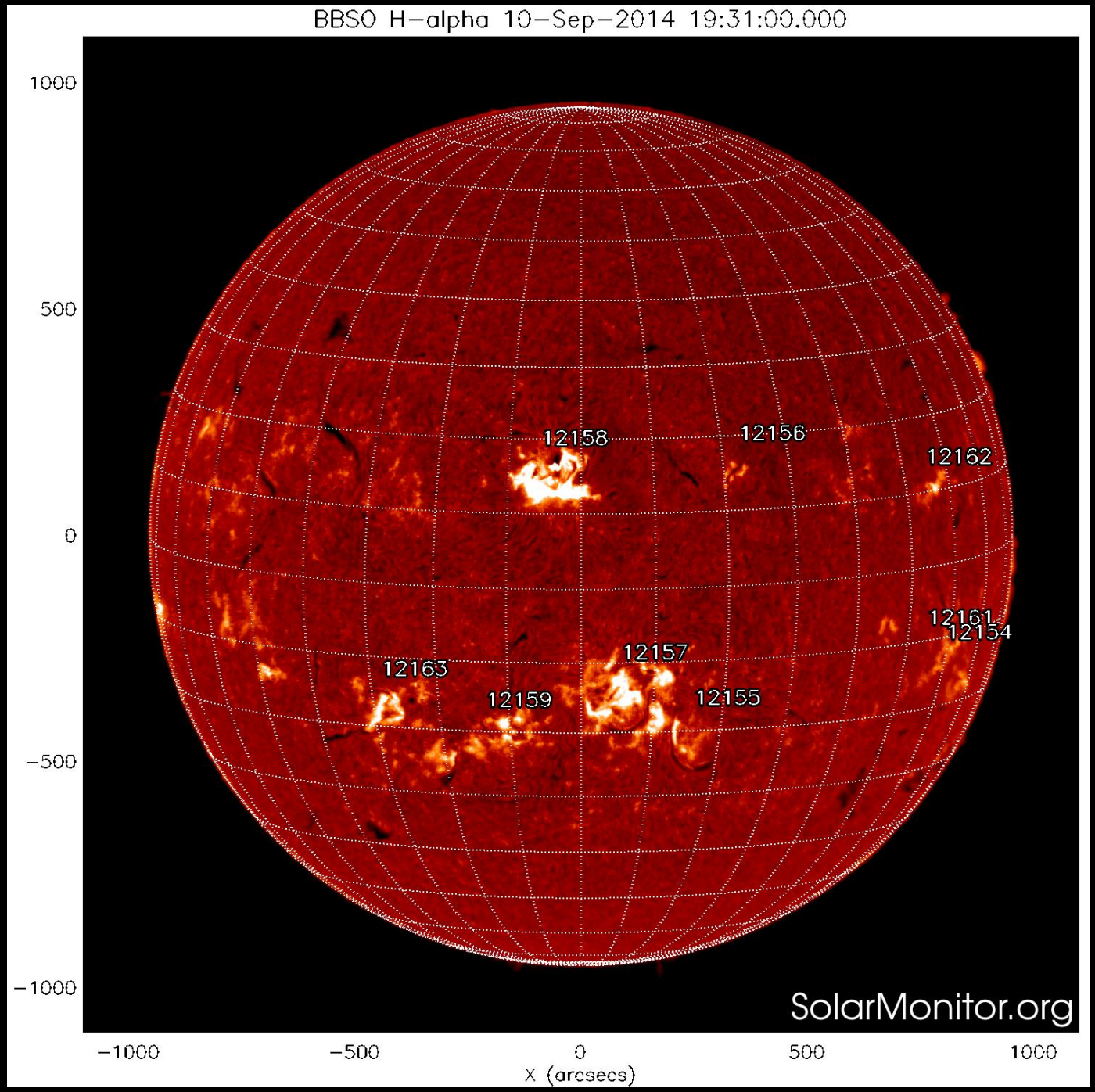
Image Used with Permission from Dr. David Hathaway

The minimum of Solar Cycle 24 and the beginning of Solar Cycle 25 was in December 2019.

Maximum is predicted to be on or after January 2024 (see ***Simple Methods for Predicting the Size and Timing of Sunspot Cycle 25*, Robert M. Wilson, Journal of the Alabama Academy of Science).**

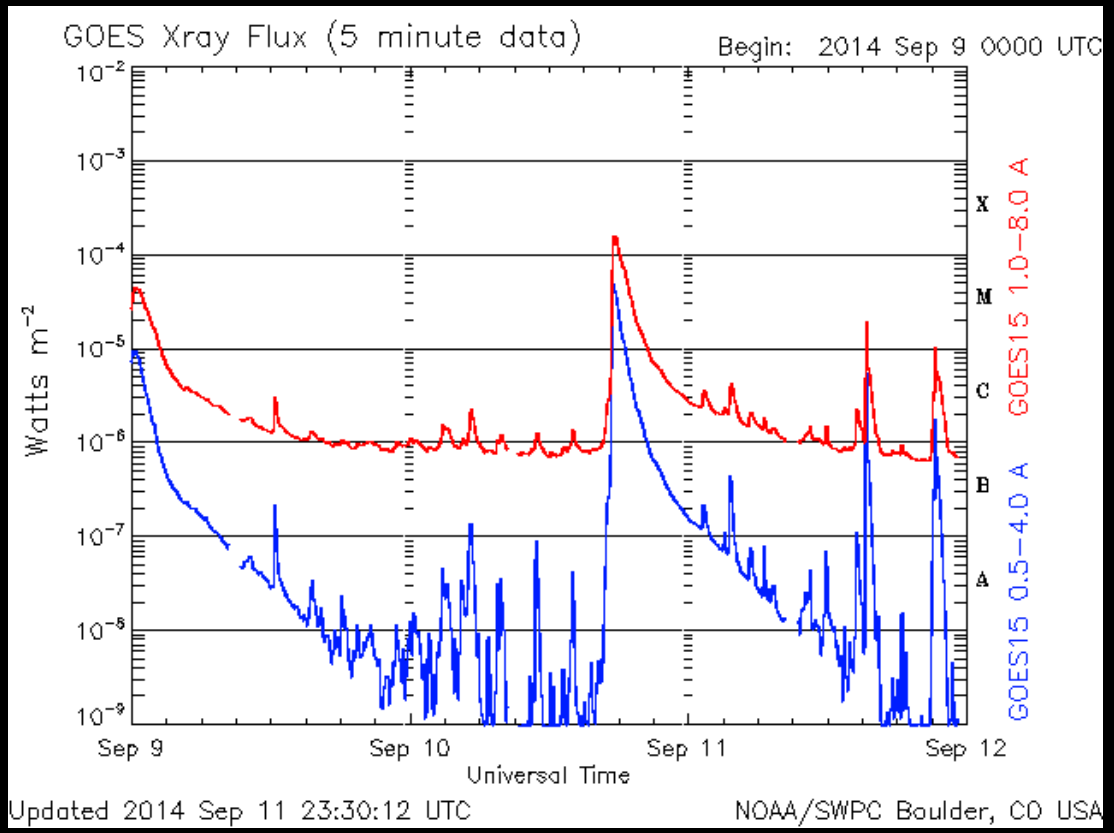
Okay, so we have graphed the number of sunspots (accurately) since the mid 1850s and made predictions about Solar Cycle 25.

So what?

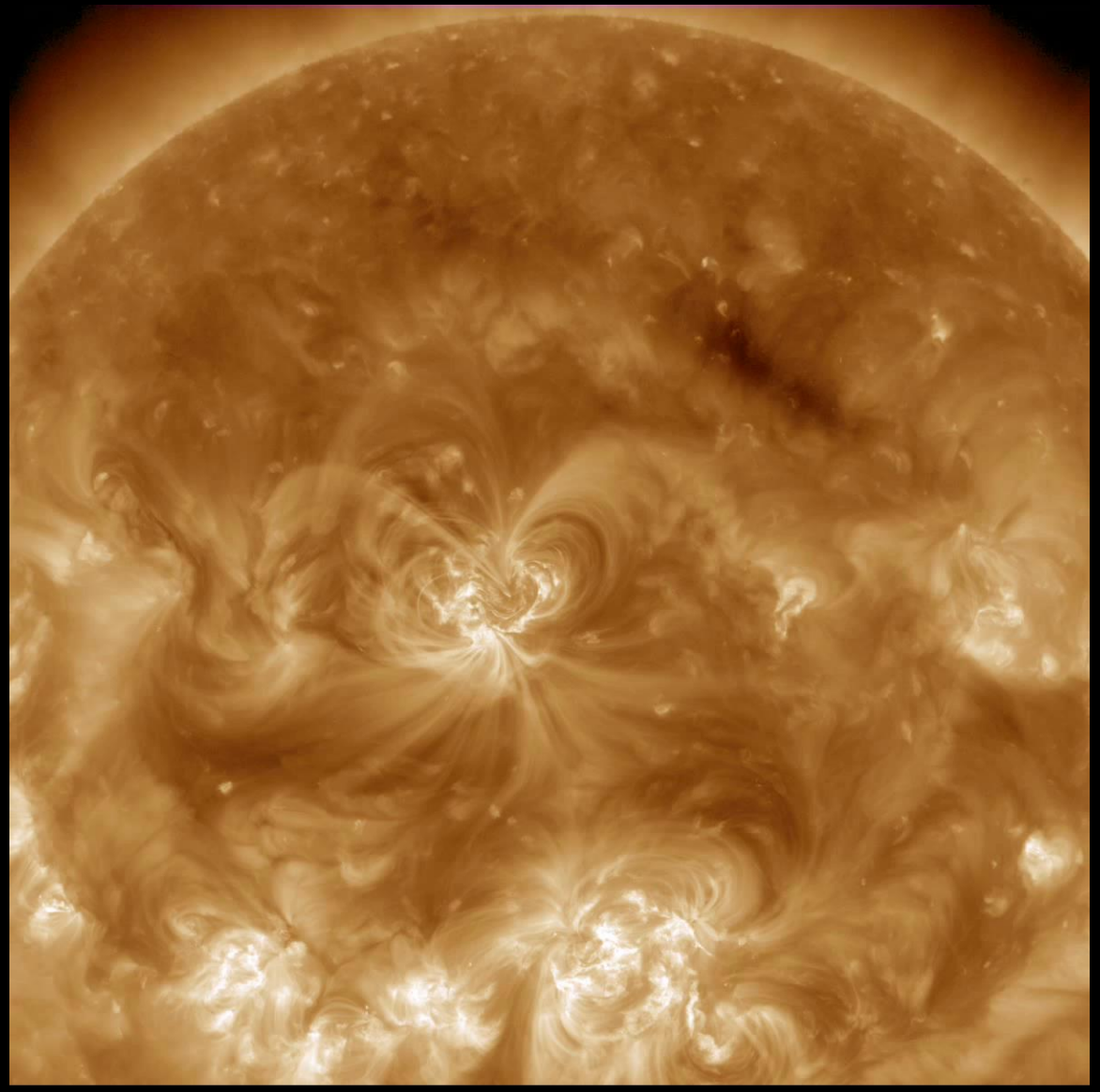


Active Region (AR) 12158 produced a X1.6 flare

[Solar Cycle 24 reached maximum in April 2014]



Flare, as Seen from the Solar Dynamics Observatory in Extreme Ultraviolet Light



Flares, such as this one, can create Coronal Mass Ejections (CMEs) that impact objects in the heliosphere

-> Space Weather

Let's Summarize So Far

The Sun is a star that produces many "colors" of light:
γ rays, X rays, UV, visible, IR, μwave, radio.

The Sun produces spots on its "surface" (photosphere), darker and cooler than the surrounding unspotted area.

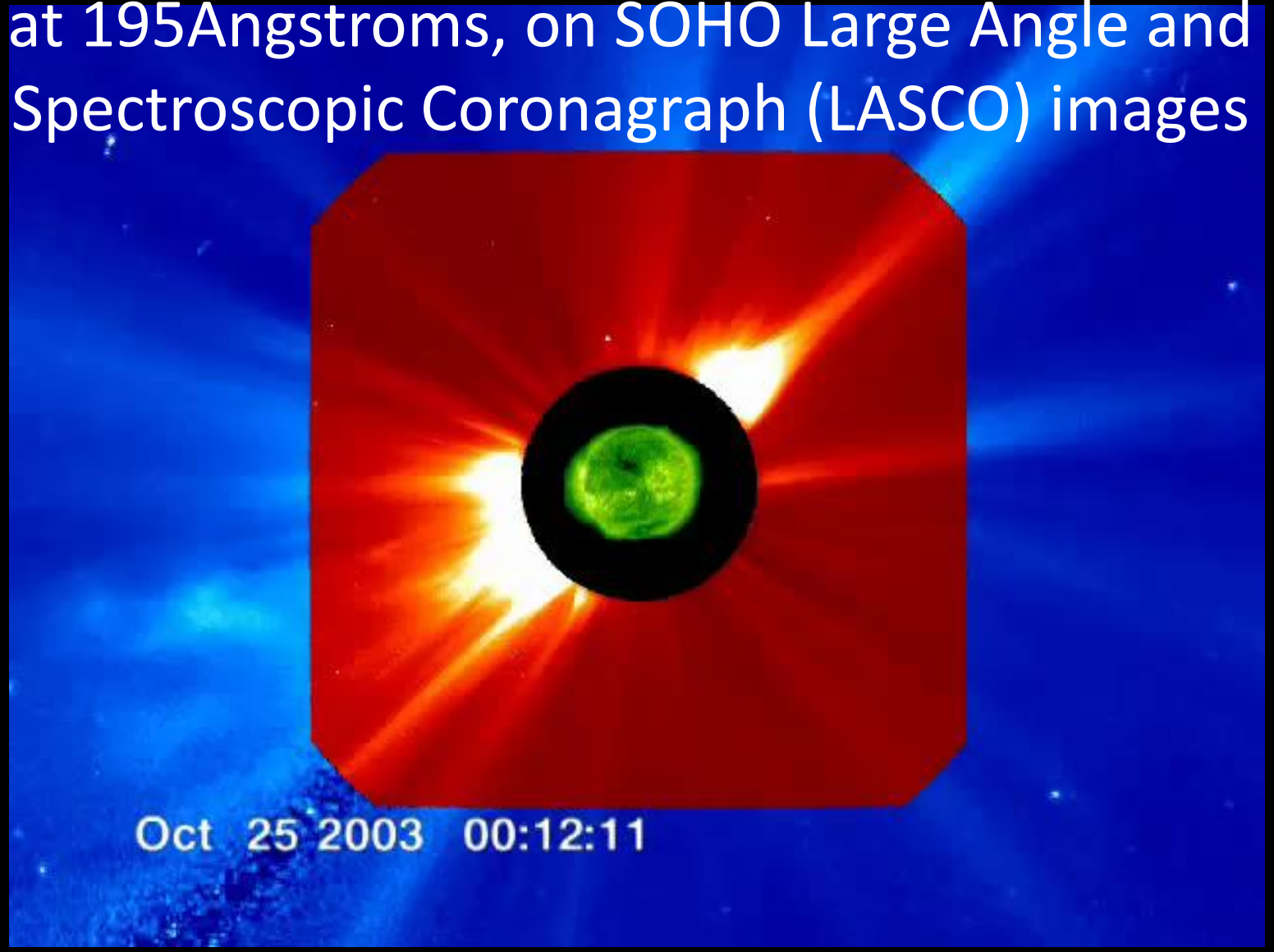
These sunspots appear and disappear cyclically, the Sunspot Cycle, with approximately eleven years between maxima or minima.

The Sun produces bursts of energy called flares. We measure flares with a satellite that detects X rays. The brightest flares are called X-class.

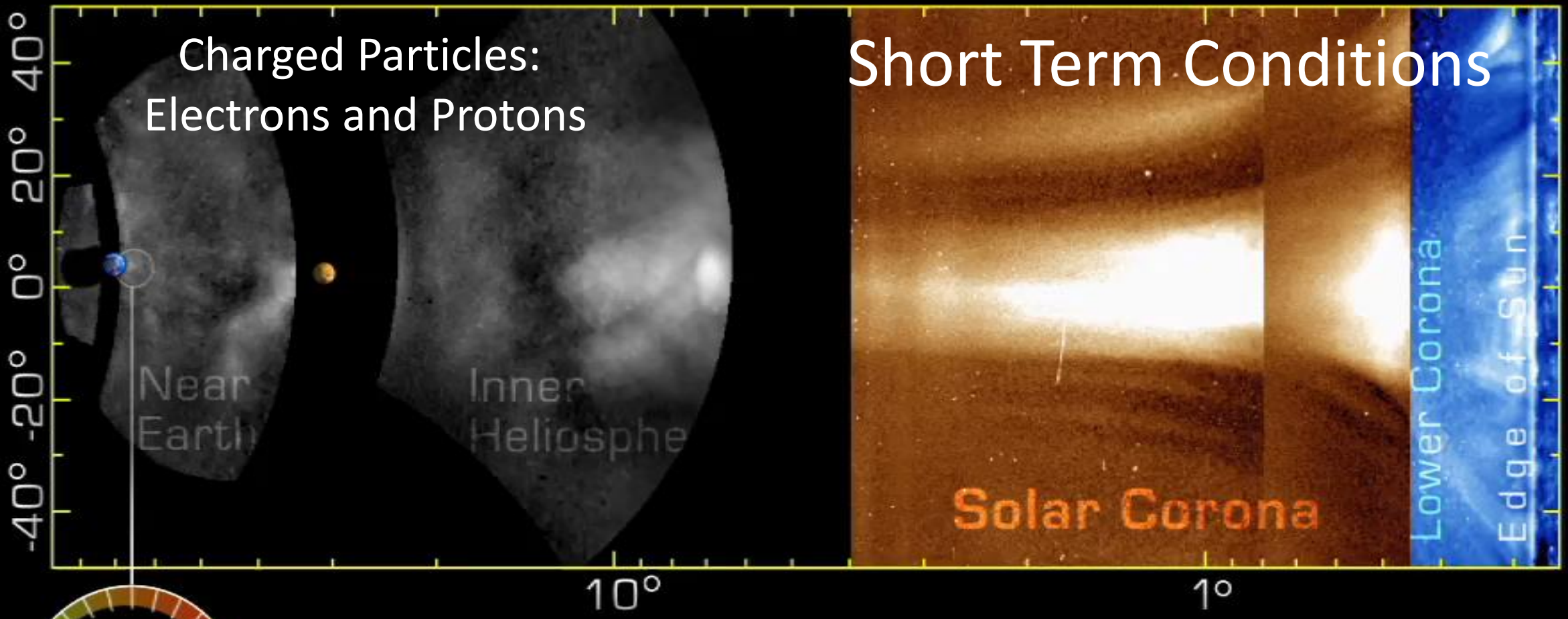
Flares and Coronal Mass Ejections give rise to Space Weather.

The “Halloween Events”

SOHO Extrememe Ultraviolet ImagingTelescope (EIT) at 195Angstroms, on SOHO Large Angle and Spectroscopic Coronagraph (LASCO) images



What is SPACE Weather?

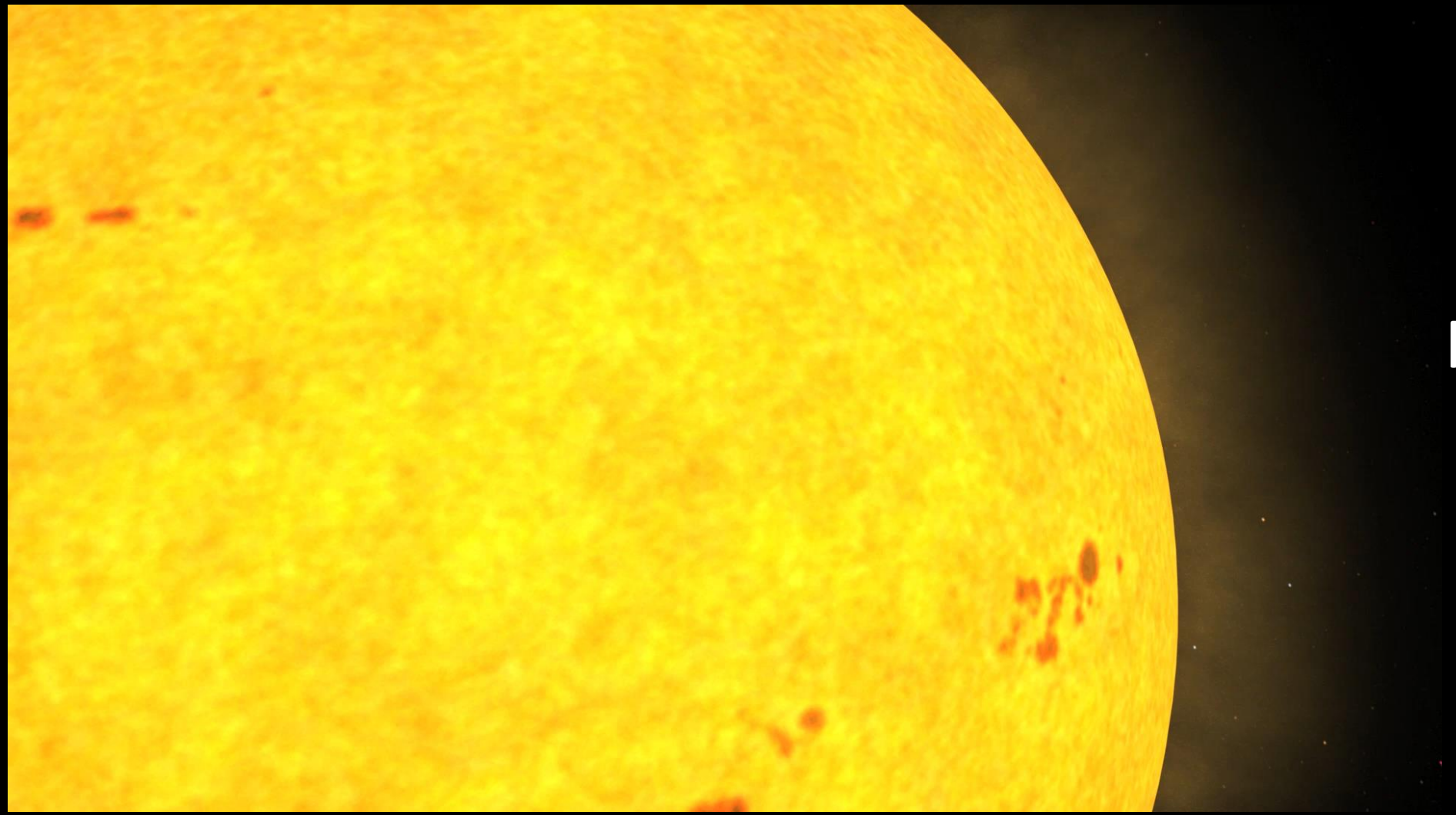


"Windy"

Animation from https://svs.gsfc.nasa.gov/10809

Credit: NASA/Goddard Space Flight Center/SwRI/STEREO/WIND

Space Weather: From Sun to Earth

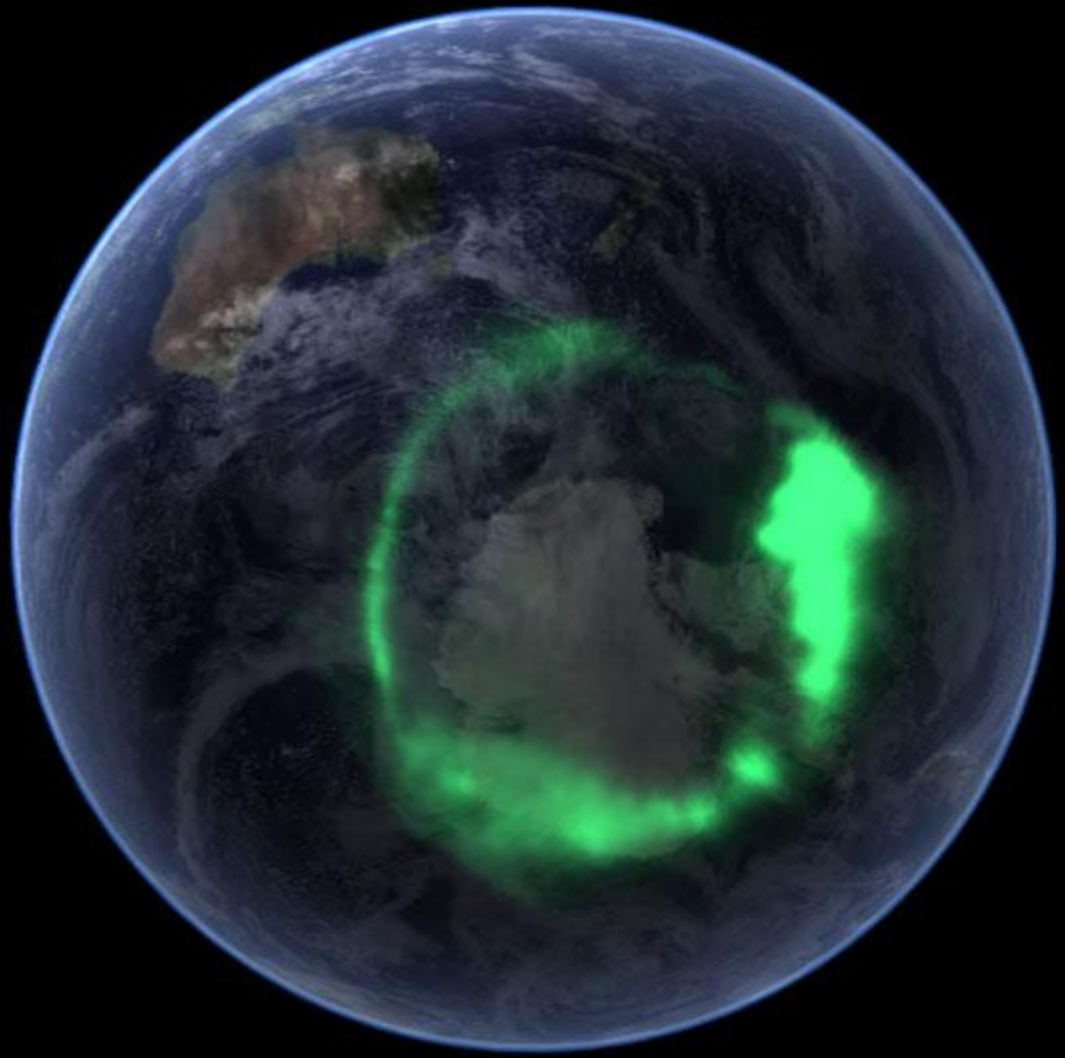


Magnetic Reconnection: At the Sun and Earth

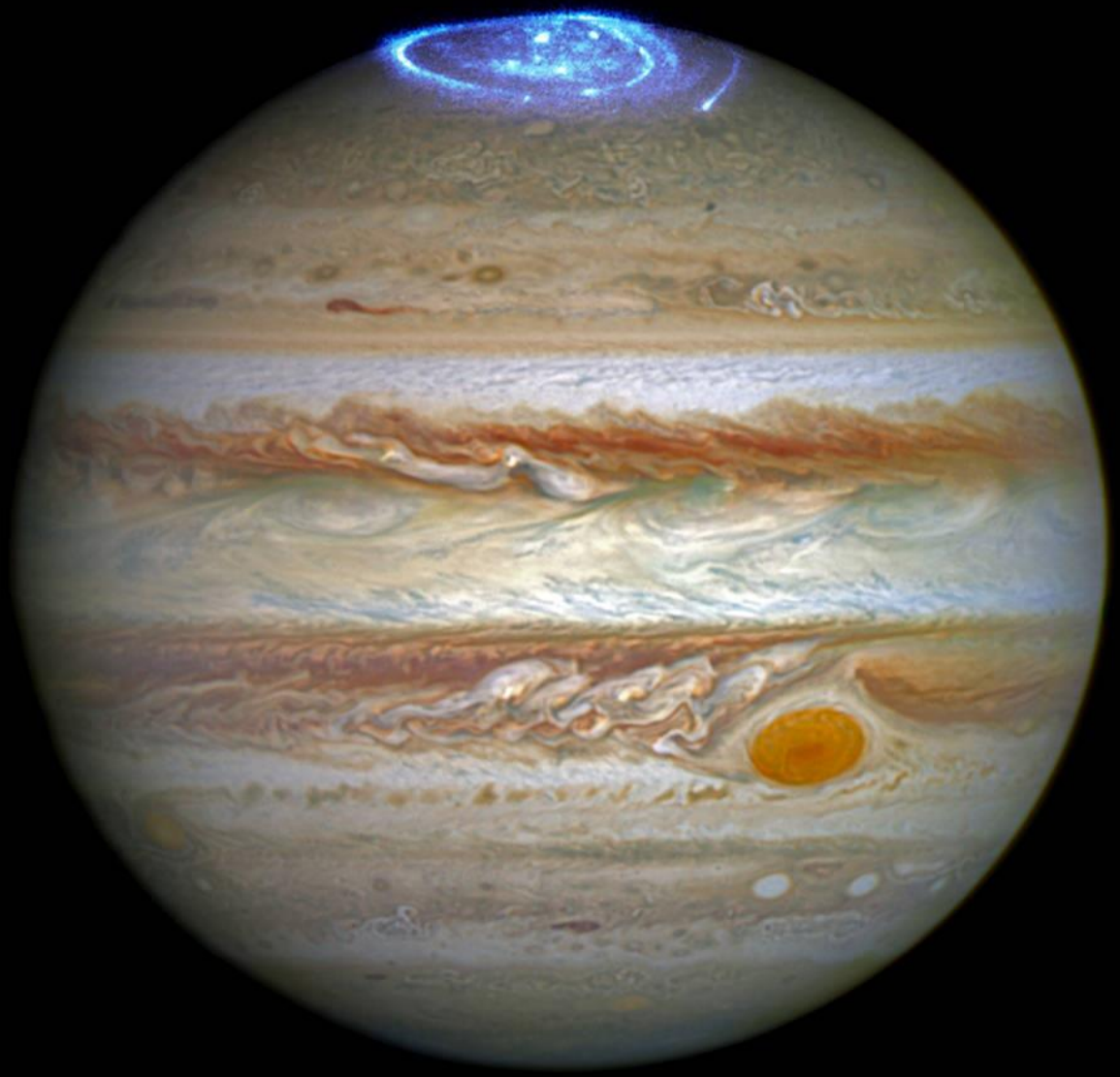
Animation from NASA/Goddard Space Flight Center Conceptual Image Lab: https://svs.gsfc.nasa.gov/20101

Auroral Oval Over Antarctica September 11, 2005

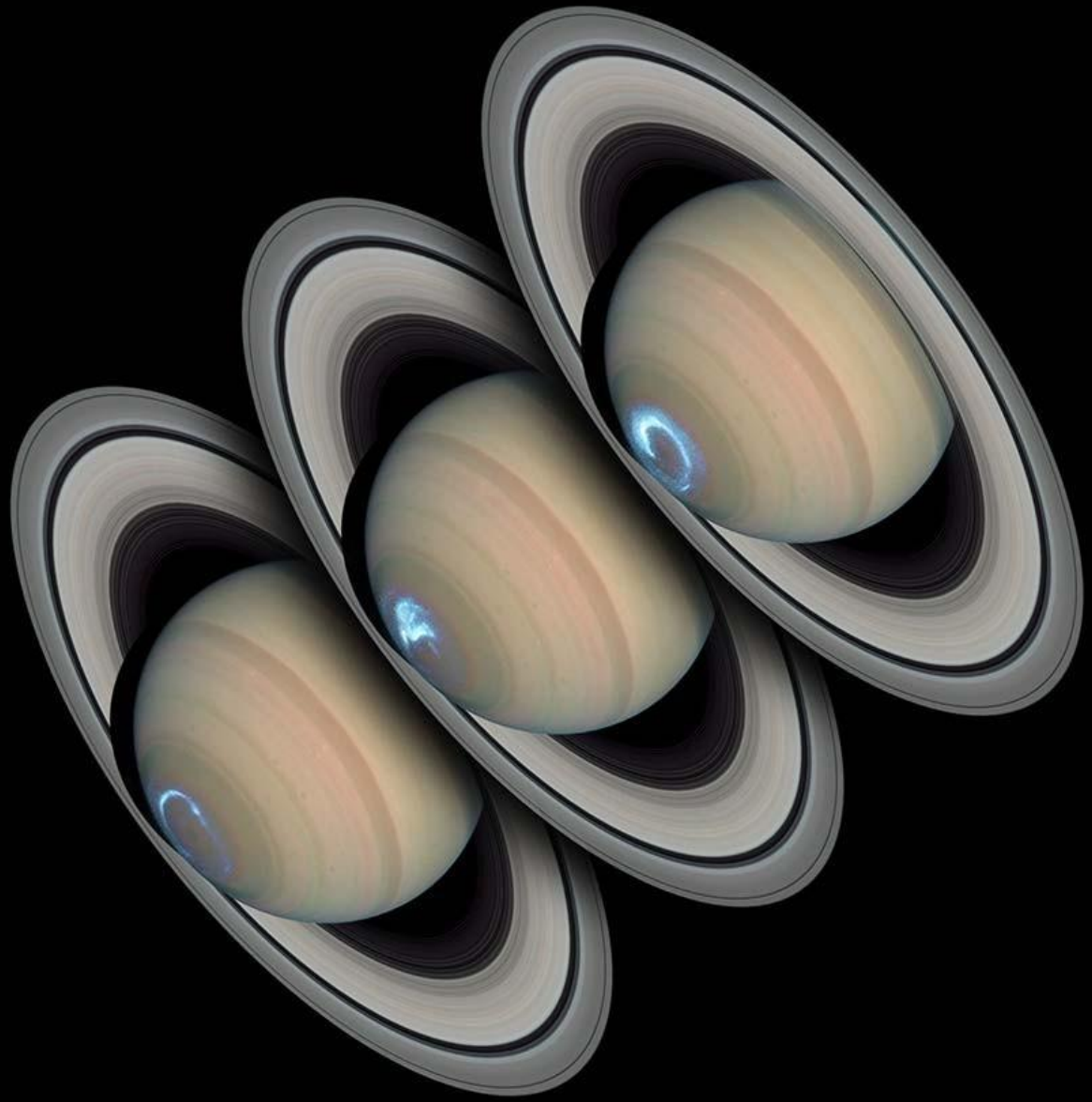
A Weather Analogy: Precipitation



Composite Image: UltraViolet-emitting auroral oval as seen from NASA's IMAGE satellite overlaid on NASA's Blue Marble image.



https://www.nasa.gov/feature/goddard/2016/hubble-captures-vivid-auroras-in-jupiter-s-atmosphere



https://solarsystem.nasa.gov/resources/12369/saturns-auroras

Space-Weather Effects

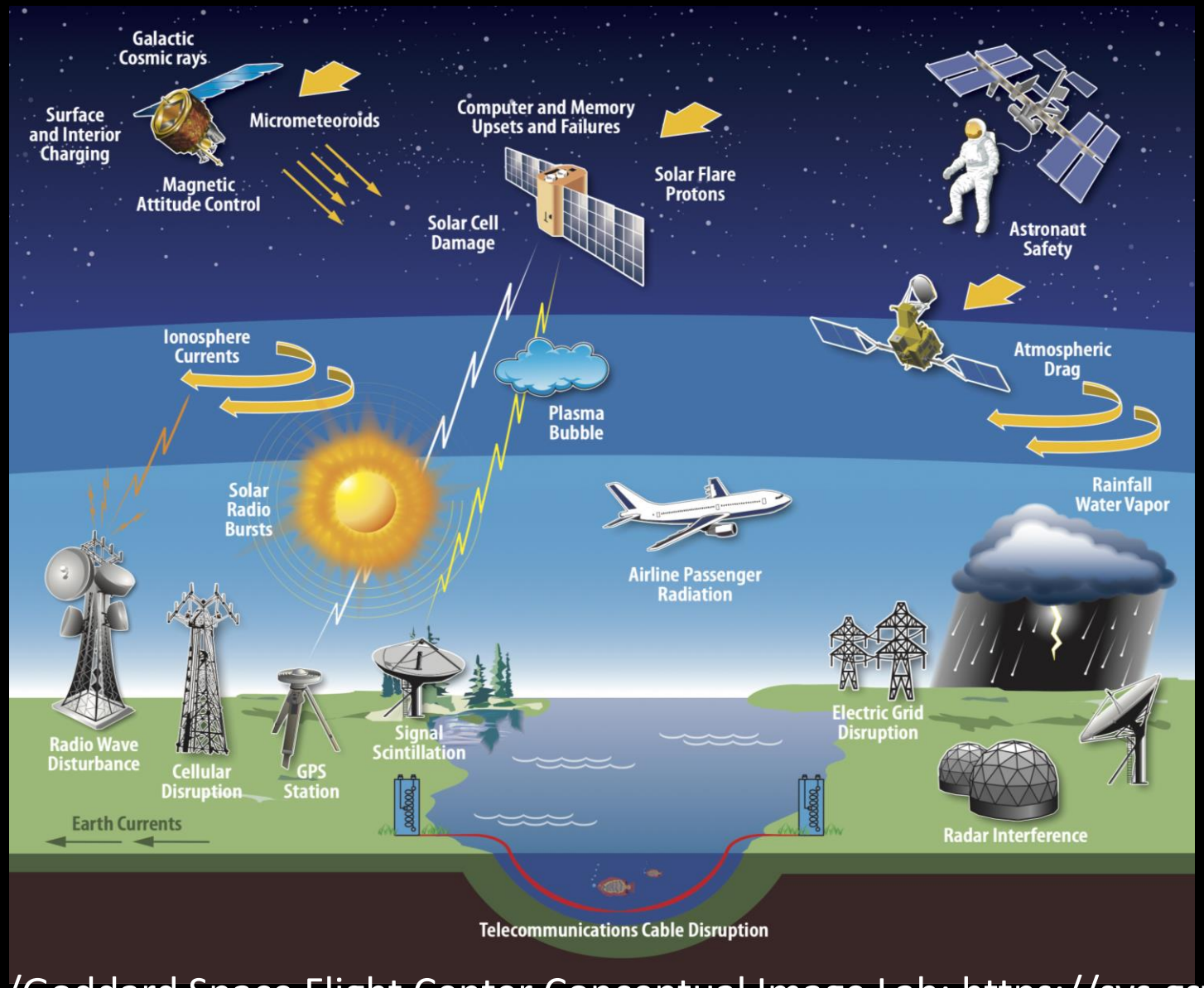


Image from NASA/Goddard Space Flight Center Conceptual Image Lab: https://svs.gsfc.nasa.gov/4923

This Just In!!

(well sort of)

From https://www.swpc.noaa.gov/news/geomagnetic-storm-conditions-likely-2-3-february-2022

February 3, 2022
SpaceX launches 49 Starlink satellites

February 4, 2022
A Minor Geomagnetic Storm Began

Summary

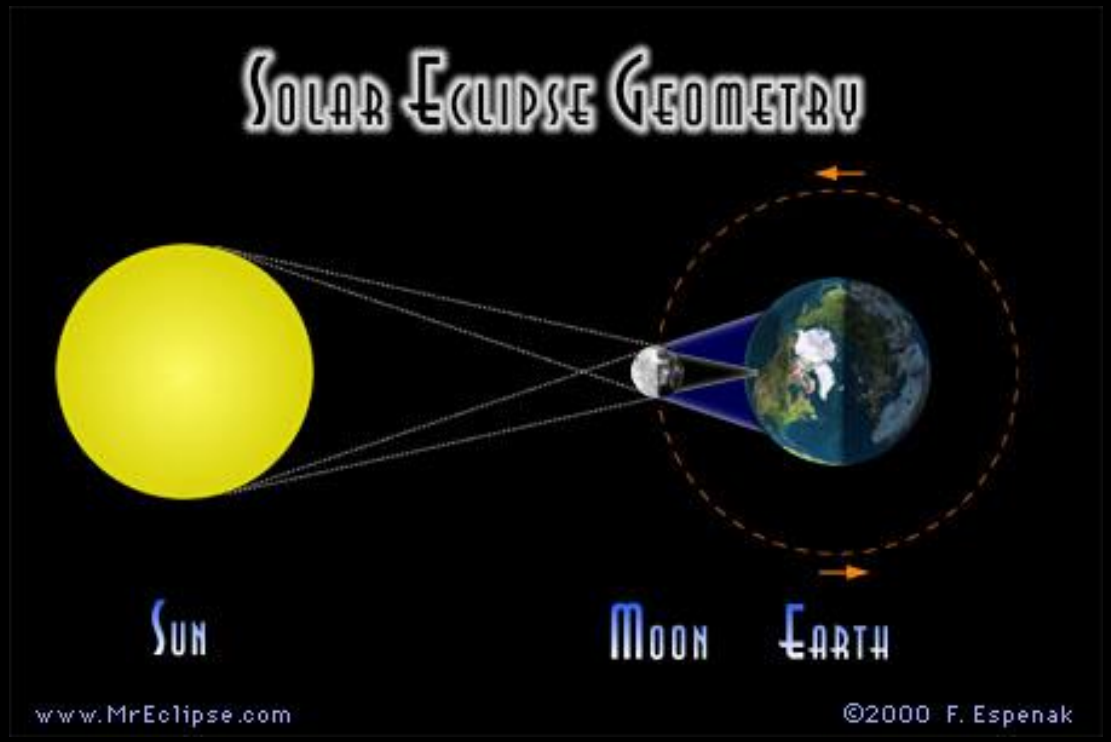
- The Sun is a Dynamic Star.
- Sunspots are cooler than their surroundings.
- The Sun has an activity cycle of approximately eleven years.
- During the maximum of a cycle, the Sun produces more spots, and is more likely to produce space-weather events…but can happen at any time.
- Space-weather events can produce effects at Earth and at any planet in the solar system with or without a magnetic field.
- Earth's magnetic field and atmosphere protects Earth from some of the most damaging effects.
- Aurorae happen when Earth's atmospheric particles, mostly electrons, precipitate back down into the lower atmosphere…energized by magnetic reconnection.
- Always check the (space) weather report.

Two Solar Eclipses over the United States

Image Used from a Presentation by Dr. Angela Speck and with permission from Michael Zeiler

What is an Eclipse?

An eclipse happens when one object blocks the light of another



Images Used With Permission from Fred Espenak

Annular: from Annulus Meaning Ring

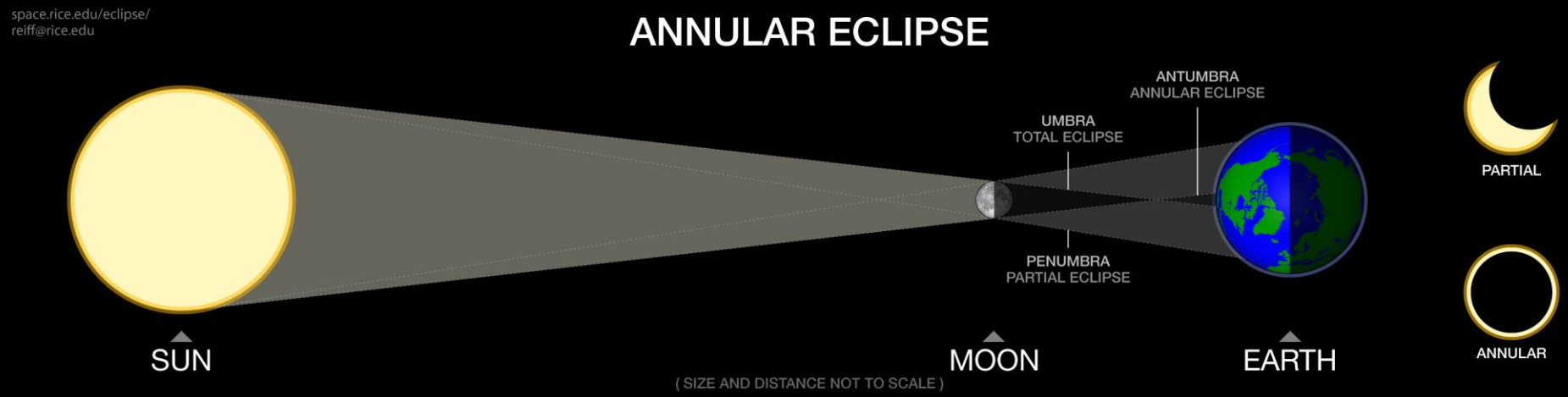
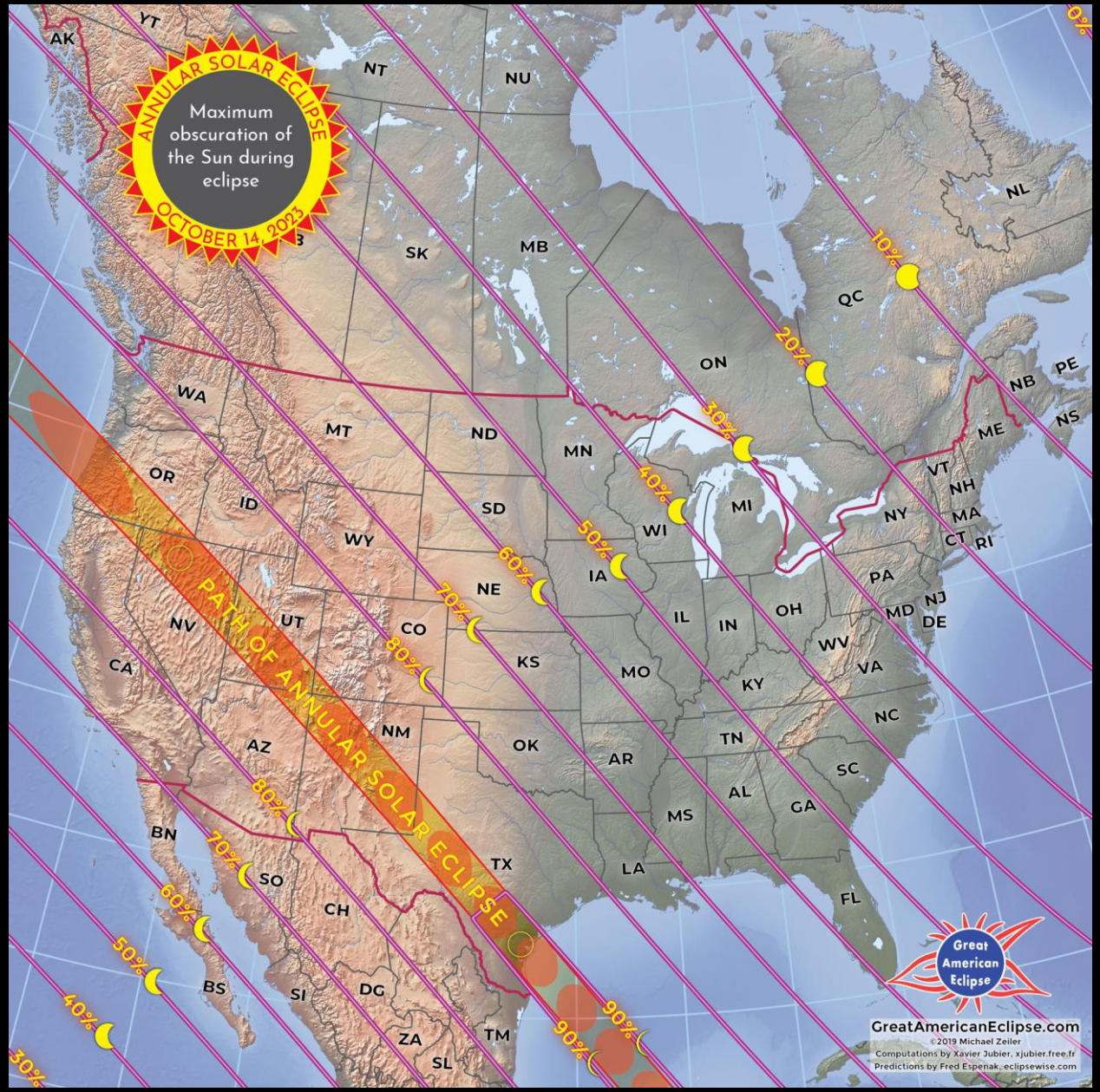


Diagram source:
https://space.rice.edu/eclipse/eclipse_graphics.html

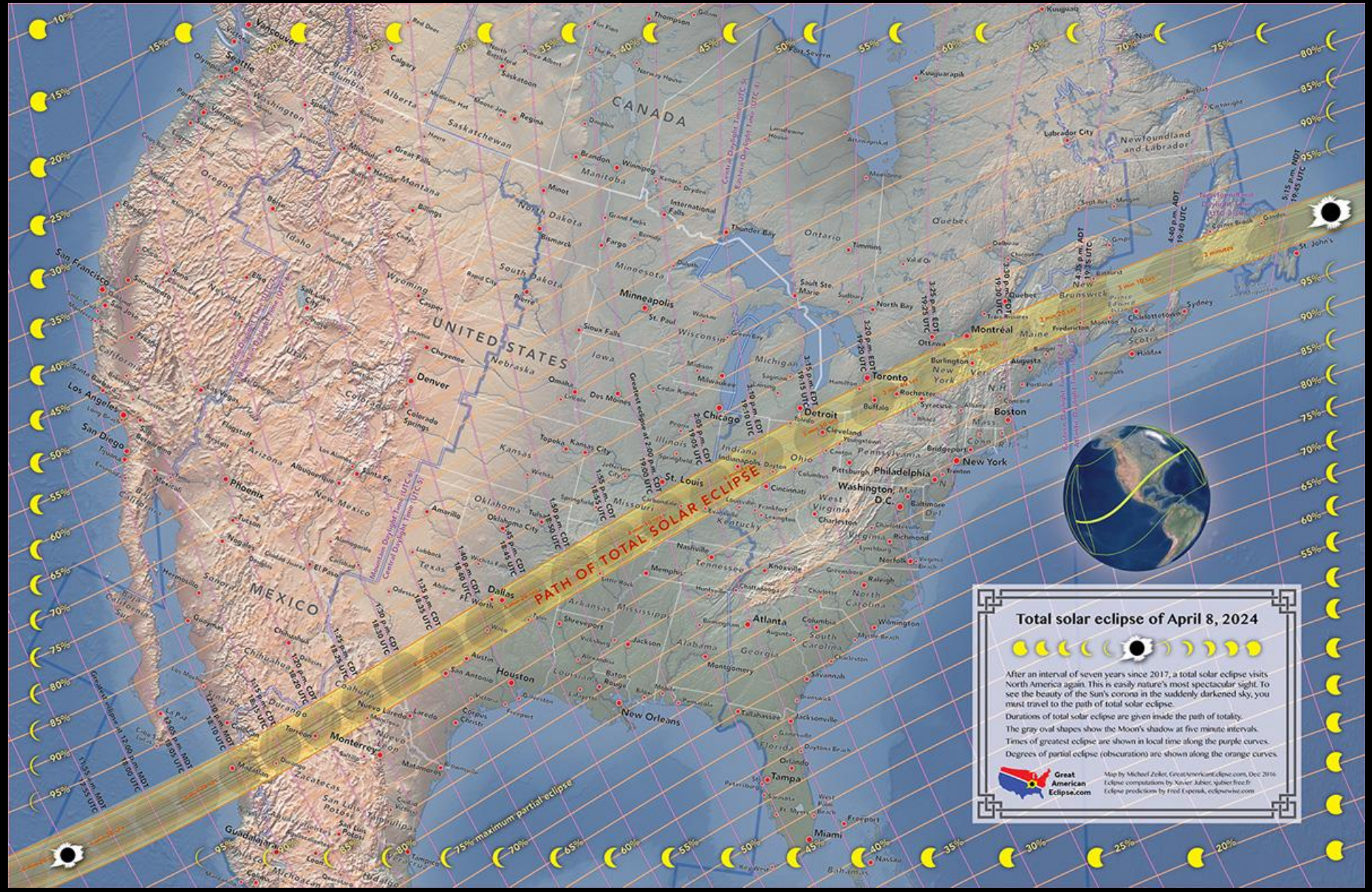
An Annular Eclipse is a Partial Eclipse with Good Press

Image Source: NASA/Bill Dunford
Published: October 12, 2022
Historical Date: May 20, 2012
An annular solar eclipse photographed on May 20, 2012
From: https://solarsystem.nasa.gov/resources/2773/may-20-2012-annular-eclipse/?annular_eclipse



From: https://solarsystem.nasa.gov/eclipses/2023/oct-14-annular/where-when/

The annular solar eclipse path crosses the United States southeast from the Pacific Coast of Oregon, exiting the U.S. in southern Texas. Image Credit: ©2021 Great American Eclipse, LLC, Used with Permission from Michael Zeiler.



From: https://solarsystem.nasa.gov/eclipses/2024/apr-8-total/where-when/

The total solar eclipse path crosses from Mexico, through the United States from Texas to Maine, and up through Canada. Image Credit: ©2021 Great American Eclipse, LLC, Used with Permission from Michael Zeiler.

What You Can See: Partial Eclipse

The entire United States will see a partial eclipse.

These images of the partial phases of the 2017 total eclipse were taken by Dr. Alphonse Sterling, NASA MSFC – Used with Permission

Maximum Eclipse at Tellico Village on April 8, 2024, 15:07 EST

The End

Rob Lucas, with Jay Pasachoff's 2013 Eclipse Expedition

Image Used With Permission